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COPRODUCTS OF COKE IN THE UNITED STATES, 1919-1947

BY

J. A. DECARLO AND J. A. CORGAN

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COPRODUCTS OF COKE IN THE UNITED STATES, 1919-1947[1]

By J. A. DeCarlo[2] and J. A. Corgan[3]

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1/ Work on manuscript completed Sept. 29, 1948. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgement is used: "Reprinted from Bureau of Mines Information Circular 7504."

2/ Commodity specialist, Anthracite and Coke Section, Bureau of Mines, Washington, D. C.

3/ Chief, Anthracite and Coke Section, Bureau of Mines, Washington, D. C.

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INTRODUCTION

The coal-carbonizing industry is recognized as one of our country's most essential industries, and this position has been achieved through its primary function as a source of supply of special fuels and chemical raw materials. When coal is carbonized at high temperatures in slot-type coke ovens in the absence of air, it decomposes into two main products - coke and crude gas. Of these, the more important is coke, a hard, strong, porous solid that remains in the oven after the volatile matter in the coal has been driven out by heat. The hot crude gas carries with it all of the coke-plant products except coke and has a complex composition in the vapor state. Its processing, to produce the four principal coproducts of coke (tar, ammonia, light oil, and gas), is accomplished by preferential condensation and absorption. Although the principal coproducts of coke - gas, tar, ammonia, and crude light oil - are of secondary importance, their

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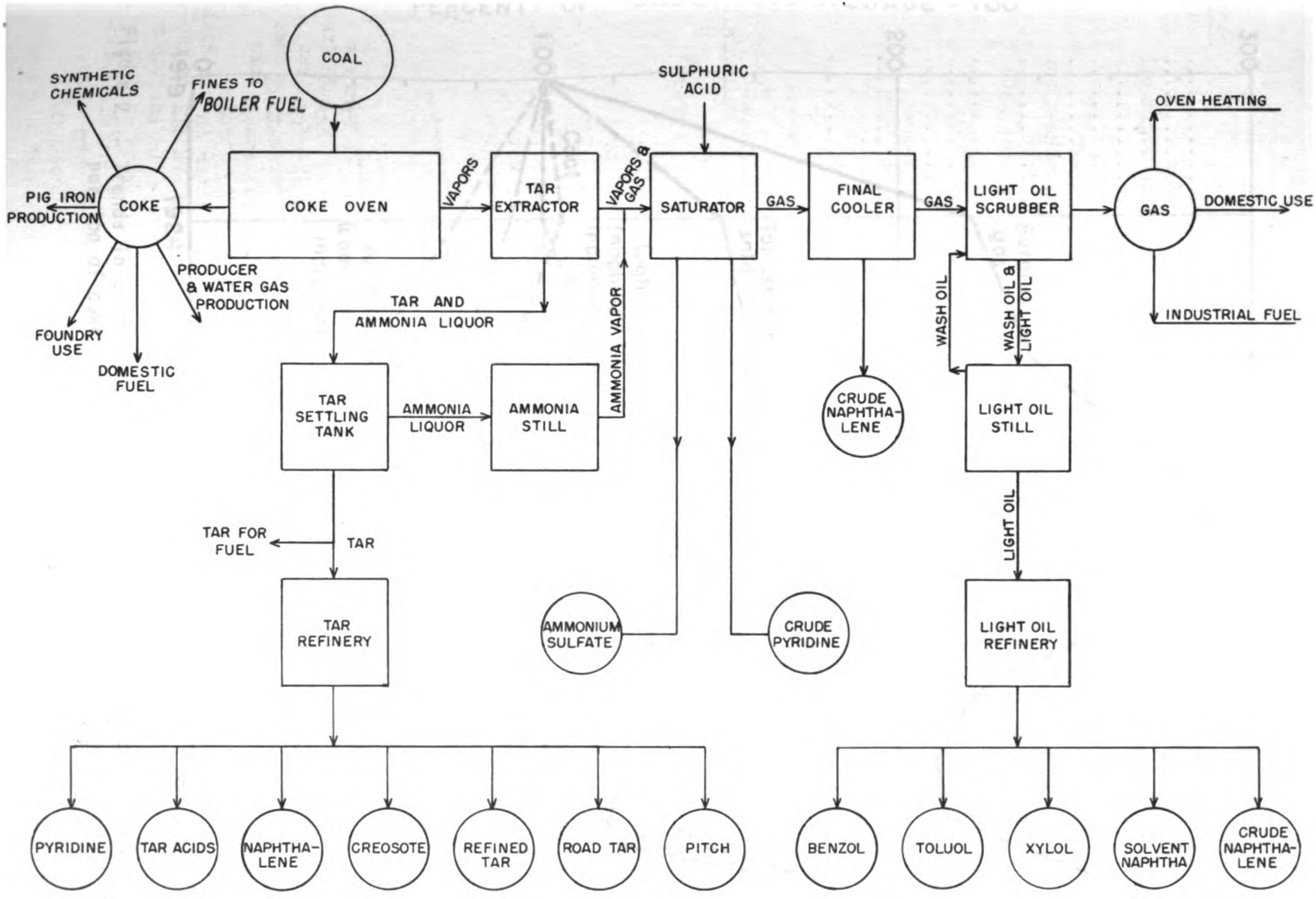

Figure 1. - Basic flow diagram for coke and coproducts.

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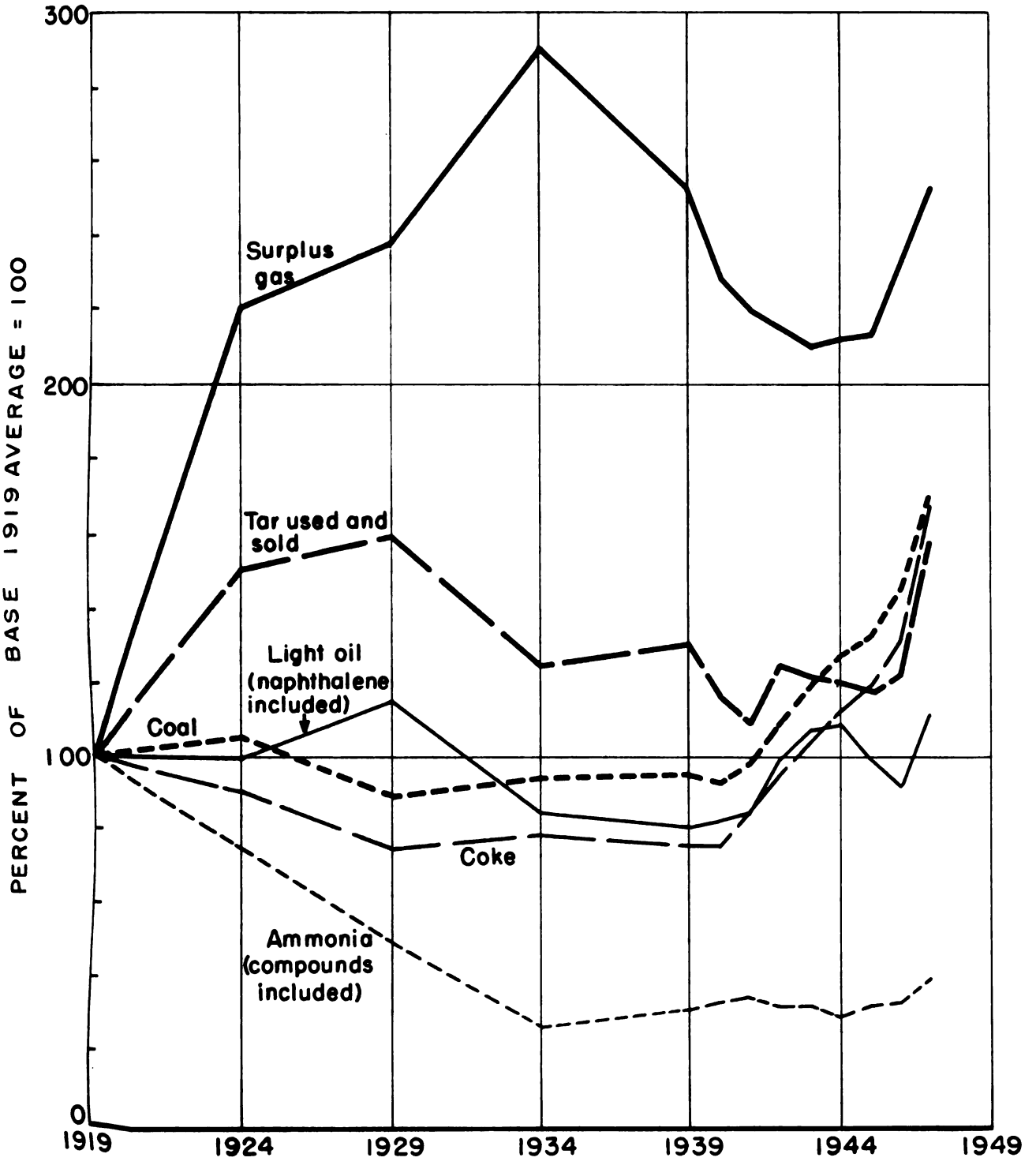

Figure 2. - Trends in cost of coal and value of coke and principal coproducts per ton of coke produced.

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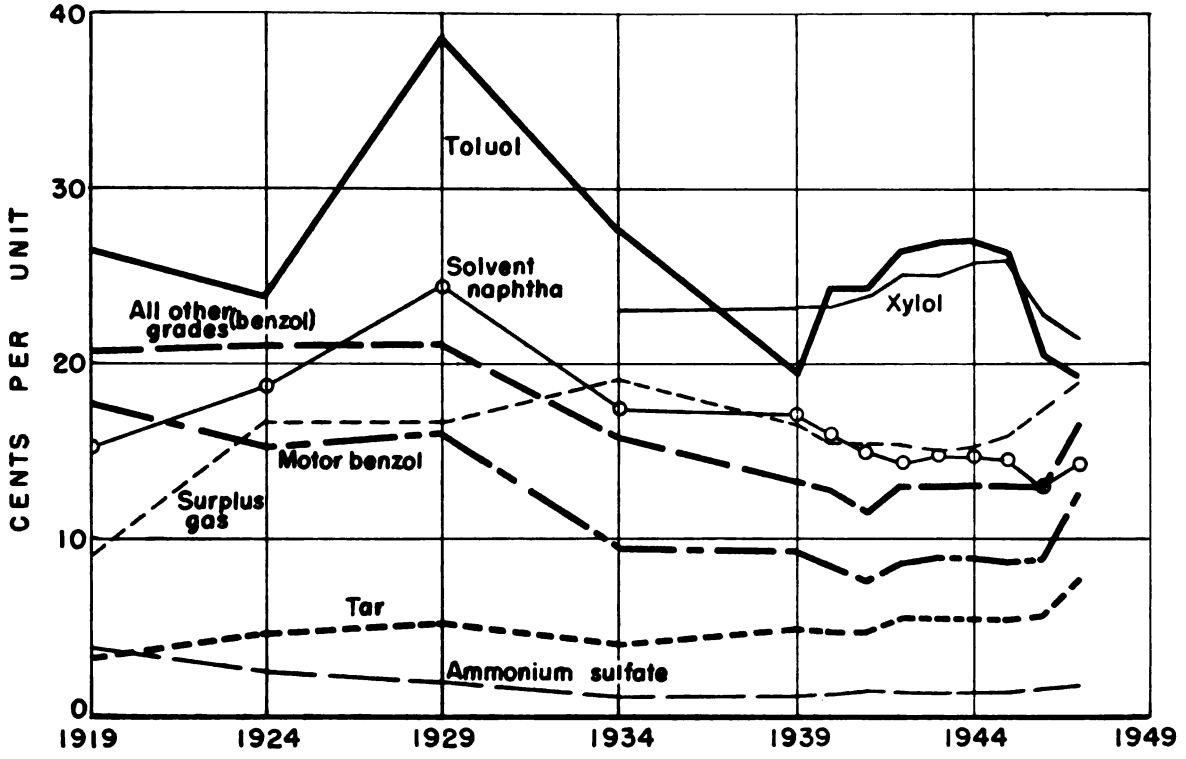

Figure 3. - Trends in receipts per unit for the principal refined light oils and other products at oven coke plants. Figures for tar, light oil derivatives, and sulfate represent cents per gallon and pound respectively; for surplus gas, cents per M cubic feet.

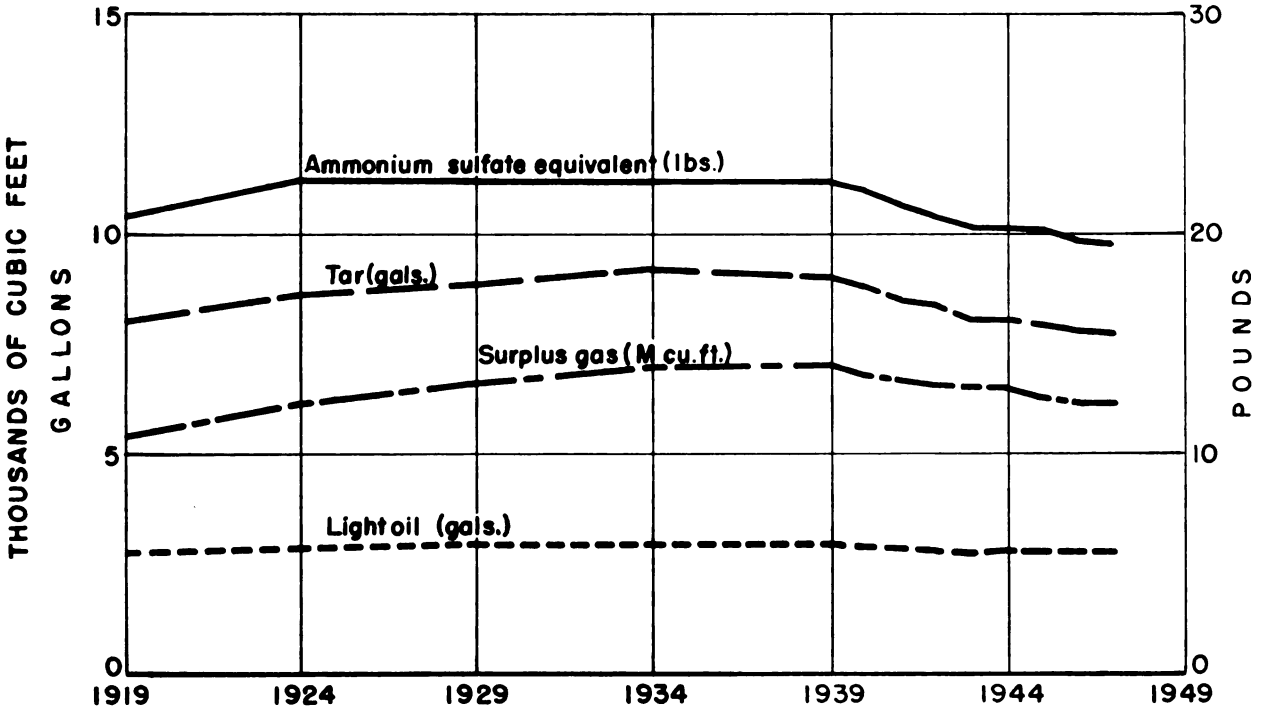

Figure 4. - Trends in yield of the principal coproducts of coke per net ton of coal carbonized. Figures for light oil and ammonium sulfate equivalent represent average for plants recovering these products.

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many and varied uses have established their essentiality to all American industry. The greater markets for products made from ammonia, crude light oil, and tar created during and since World War II stimulated manufacturing interest, and coke-plant operators have strenuously engaged in developing special technical processes, equipment, and operating technique to economically produce these commodities. In view of these developments, this report has been prepared to show the trend in production, sales, values, and yields of all products except coke and breeze for the period 1919-1947. The following discussions and compilations concern products recovered at coke plants proper and do not include finished products obtained from raw materials originating at coke plants but produced in final form by chemical manufacturers. No attempt is made to review the many scientific and technical improvements made in coal carbonization during the period under study.

ACKNOWLEDGEMENTS

The data contained in this summary were obtained from monthly and annual reports voluntarily submitted to the Bureau of Mines by coke-plant operators. Their splendid cooperation with the Bureau is appreciated.

SUMMARY

The available supplies of the coproducts of coke (gas, tar, ammonia, and crude light oil) are more or less fixed by the activity in the coke industry, and the relative outputs of coke and the principal coproducts are approximately parallel. Recovery at the coke plants of the coproducts and individual compounds made therefrom represents, to the operators, a source of revenue and a means of reducing the cost of converting coal to coke. Although production, and consequently gross financial returns from the sales of these products, has increased substantially since 1919, the revenue obtained through the sale of the coproducts has not been proportionally as great as the rise in the cost of coal and the reported value of coke. As shown in table 1, the total value of coproducts of coke sold in 1919 was equivalent to 28.1 percent of the value of all products; in 1929, it had increased to 36.7 percent, but since that time there has been a definite downward trend, and in 1947 it amounted to only 23.2 percent. The coproducts values in 1947 were only 37 percent higher than in 1919, although coke value had increased 67 percent and the cost of coal 70 percent. This is shown in detail in table 2, which indicates the shifts in income from the different products. In 1919, ammonia in the forms of sulfate and liquor supplied the greatest income, mainly because of the high unit value prevailing at that time. Coke-oven gas assumed leadership over ammonia as the principal source of revenue (outside of coke) in 1921, a position it has maintained since. In evaluating the significance of this change, it must be remembered that before 1920 most of the coke-oven gas was used as a metallurgical fuel and was credited to the ovens at a very low cost. About 1921, the trend toward the use of coke-oven gas for supplying base-load city gas was indicated by the larger average price returns for this product. Light oil and its derivatives forged ahead of ammonia in 1929 as a source of revenue. The decline in revenue from ammonia sales since 1920 is due to the remarkable expansion of synthetic plants, which produce ammonia from hydrogen and atmospheric nitrogen. The income from tar has increased markedly since 1920, not only because of the higher unit value but also because of the decline in the use of crude tar as furnace fuel and the increased sales of this commodity on the open market.

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TABLE 1. - Relationship of value of coproducts of coke sold to value of all products used or sold by coke-plant operators

Year	Value of coproducts sold	Value of all products used or sold	Percent of coproducts to all products
1919.....	$63,727,790	$226,423,429	28.1
1924.....	103,802,507	315,519,863	32.9
1929.....	163,675,571	446,275,847	36.7
1934.....	92,865,828	257,948,003	36.0
1939.....	124,814,434	343,258,986	36.4
1940.....	145,081,877	421,724,496	34.4
1941.....	158,809,184	490,868,434	32.4
1942.....	176,932,465	571,142,055	31.0
1943.....	181,929,705	623,209,061	29.2
1944.....	185,995,242	686,910,035	27.1
1945.....	172,138,205	660,769,562	26.1
1946.....	157,389,875	623,005,548	25.3
1947.....	222,093,651	958,766,918	23.2

TABLE 2. - Value of coal, coke, breeze, and coproducts per ton of coke produced

Year	Coal	Coproducts sold					
		Ammonia and its compounds	Light oil and its derivatives, including naphthalene	Surplus gas sold or used	Tar	Miscellaneous products	Total
1919.....	$5.65	$1.064	$0.508	$0.662	$0.275	$0.026	$2.535
1924.....	5.95	.800	.505	1.465	.283	.002	3.055
1929.....	5.04	.537	.585	1.578	.318	.046	3.064
1934.....	5.33	.284	.434	1.924	.349	.025	3.016
1939.....	5.36	.341	.414	1.676	.387	.092	2.910
1940.....	5.23	.364	.421	1.507	.297	.097	2.686
1941.....	5.53	.371	.431	1.454	.314	.145	2.715
1942.....	6.18	.348	.501	1.426	.388	.177	2.840
1943.....	6.70	.355	.546	1.390	.385	.178	2.854
1944.....	7.16	.324	.552	1.403	.327	.167	2.773
1945.....	7.45	.356	.503	1.413	.352	.148	2.772
1946.....	8.17	.361	.467	1.542	.395	.154	2.919
1947.....	9.60	.423	.566	1.678	.464	.196	3.327

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TABLE 2. - Value of coal, coke, breeze, and coproducts per ton of coke produced (Cont'd.)

Year	Tar used, not sold1/	Value of coproducts	Breeze produced	Coke produced	Value of coke breeze, and coproducts
1919.....	-	$2.535	$0.097	$6.375	$9.007
1924.....	$0.290	3.345	.182	5.759	9.286
1929.....	.291	3.355	.199	4.801	8.355
1934.....	.125	3.141	.185	5.052	8.378
1939.....	.110	3.020	.170	4.815	8.005
1940.....	.145	2.831	.157	4.820	7.808
1941.....	.104	2.819	.163	5.411	8.393
1942.....	.085	2.925	.175	6.068	9.168
1943.....	.078	2.932	.191	6.654	9.777
1944.....	.131	2.904	.198	7.140	10.242
1945.....	.095	2.867	.202	7.572	10.641
1946.....	.071	2.990	.217	8.345	11.552
1947.....	.141	3.468	.242	10.652	14.362

1/ Does not include value of tar distilled.

The trend in gross value of coproducts per ton of coke, as shown in table 2, is due principally to changes in unit prices. Table 3 shows the substantial rise in unit prices of tar and surplus gas and the decline in prices of ammonia, benzol, and toluol. Although benzol prices have declined since 1919, income from the sale of this commodity has increased substantially in recent years because of the shift in production from motor benzol to the industrial grades, which command higher prices. Prices of toluol fluctuated from 38.6 cents per gallon in 1929 to 19.4 cents in 1939; solvent naphtha and xylol remained fairly constant during the period under review, whereas crude naphthalene, after declining from 2 cents per pound in 1919 to 1.3 cents in 1934, increased to 3.1 cents in 1947. The greatest decrease in price of any of the coal products since 1919 has been for ammonia in the forms of sulfate and liquor, which declined more than 57 percent and 71 percent, respectively.

As indicated in table 4, the average yields of tar, ammonia, and light oil per ton of coal carbonized increased in the period between the two world wars, whereas the yield of gas declined. The gain in yield of tar, ammonia, and crude light oil was due to the more careful selection of coals for coproduct yields and improvement of apparatus. Better oven design has reduced the gas needed for underfiring and the increased use of producer and blast-furnace gas for heating ovens released more surplus gas for distribution. Thus, the quantity of surplus gas made available increased from 5.38 MCF per ton of coal carbonized in 1919 to a peak of 7.09 MCF in 1939. Although declining somewhat from that figure in recent years, it has remained well over 6 MCF per ton of coal charged in spite of the decline in total yield of gas. Beginning with World War II, the upward trend in yields of all products was halted. This may be attributed to the deterioration of old ovens, poorer quality of coals charged, and to the higher carbonizing temperatures and shorter coking periods that have been employed by coke-plant operators generally, in order to obtain maximum production of coke.

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TABLE 3. - Average receipts (at producing plants) per unit of coproducts sold, in cents

Year	Tar, Gallons	Ammonia: Sulfate, pounds	Ammonia: Liquor, pounds	Surplus gas, M cubic feet	Benzol: Motor, gallons	Benzol: All other grades, gallons	Toluol crude and refined, gallons	Xylol crude and refined, gallons	Solvent naphtha, gallons	Crude naphthalene, pounds
1919.....	3.2	3.8	11.0	8.6	17.6	20.6	26.3	(1)	15.2	2.0
1924.....	4.6	2.4	9.8	16.5	15.2	21.1	23.8	(1)	18.7	1.5
1929.....	5.1	1.8	5.1	16.6	15.9	21.1	38.6	(2)	24.2	1.6
1934.....	3.9	1.0	2.9	19.1	9.4	15.7	27.5	23.0	17.4	1.3
1939.....	4.8	1.1	3.1	16.6	9.2	13.2	19.4	23.2	17.0	1.6
1940.....	4.6	1.2	3.2	15.5	8.4	12.7	24.2	23.2	15.9	1.7
1941.....	4.7	1.3	3.3	15.3	7.6	11.6	24.2	23.7	15.1	1.8
1942.....	5.4	1.3	3.5	15.2	8.6	13.0	26.5	25.0	14.3	2.0
1943.....	5.4	1.3	3.7	15.0	9.0	13.0	26.9	24.9	14.8	2.1
1944.....	5.4	1.3	3.2	15.2	8.9	13.1	27.1	25.7	14.7	2.0
1945.....	5.3	1.3	3.0	15.8	8.6	13.0	26.3	25.8	14.4	2.1
1946.....	5.6	1.4	3.0	17.3	8.8	12.9	20.5	22.7	12.9	2.2
1947.....	7.6	1.6	3.1	18.9	11.6	16.4	19.2	21.4	14.3	3.1

1/ Not available. 2/ Included with solvent naphtha.

TABLE 4. - Average yield of coke and coproducts per ton of coal carbonized

Product	1919	1924	1929	1934	1939	1940	1941	1942	1943	1944	1945	1946	1947
Coke.....pounds	1,402	1,386	1,392	1,389	1,401	1,411	1,416	1,416	1,416	1,420	1,419	1,413	1,412
Tar.....gallons	8.06	8.60	8.87	9.22	9.06	8.79	8.52	8.41	8.11	8.13	7.95	7.82	7.78
Ammonium sulfate or equivalent, pounds	20.82	22.20	22.31	22.29	22.33	22.00	21.34	20.85	20.32	20.29	20.22	19.79	19.66
Crude light oil.....gallons	2.72	2.89	2.93	2.90	2.99	2.93	2.90	2.88	2.83	2.87	2.84	2.77	2.75
Gas.....M cubic feet	11.59	11.03	10.98	11.13	11.03	10.89	10.81	10.74	10.68	10.68	10.33	10.26	10.27
Surplus sold or used..... do.	5.38	6.14	6.61	6.98	7.09	6.84	6.71	6.66	6.59	6.58	6.33	6.29	6.27
Burned in coking process. do.	5.92	4.67	4.13	3.97	3.80	3.89	3.97	3.91	3.90	3.95	3.85	3.85	3.87
Wasted..... do.	.29	.22	.24	.18	.14	.16	.13	.17	.19	.15	.15	.12	.13

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COKE-OVEN GAS

Coke-oven gas, second to coke, is the most valuable product of coal carbonization if judged either as a source of income or in calorific value. Coke ovens are by far the largest producers of manufactured gas in the United States and are an important factor in the distribution of gaseous fuel to affiliated and neighboring industries, public utilities, and communities. Adaptation of high-temperature slot-type coke ovens to the needs of city gas manufacture led a number of companies to install batteries of coke ovens to supplement or even replace their coal- or water-gas plants. The number of plants owned by city gas companies increased from 9 in 1919 to a peak of 23 in 1934. The development of long-distance (1,000 miles and more) pipe lines for transporting natural gas, however, has materially affected the position of coke ovens as a source of city gas, and a number of plants have been abandoned because of the substitution of natural gas for coke-oven gas. Thus, the number of coke plants owned by city gas companies declined from 23 in 1934 to 13 in 1947.

Most of the oven-coke plants supplying metallurgical coke are operated in conjunction with steel plants, and a large proportion of the gas is used in the steel plant for heating purposes. There are, however, a few steel-plant ovens that make more gas than they can use and therefore sell some of the surplus to city gas companies. In 1947, 22 furnace plants supplied 54,353,415 MCF, or 32.4 percent, of the total quantity of coke-oven gas distributed through city mains.

Since the early 20's, a number of coke plants have increased their income by heating the coke ovens with low B.t.u. gas, blast-furnace gas (100 B.t.u. per cubic foot), or producer gas (130 B.t.u. per cubic foot), thus releasing a greater proportion of the much higher-value coke-oven gas (550 B.t.u. per cubic foot) for sale to the city distributing company. This is clearly indicated in table 7, which shows that the proportion of coke-oven gas used to heat the ovens dropped from 51 percent of the total output in 1919 to 37.6 percent in 1929 and since that time has remained fairly constant.

The income from surplus coke-oven gas accounted for about 50 percent of the total revenue derived from the sales of all coproducts since 1921 (table 5). The total value of the surplus gas sold or used by the producers increased from $16,650,195 in 1919 to a record of $112,008,007 in 1947. As shown in table 3, the average unit value of surplus coke-oven gas increased from $0.086 per M cubic feet in 1919 to a peak of $0.191 per M cubic feet in 1934. The average unit value of surplus gas is governed largely by the proportion of gas sold for distribution through city mains, as this gas always commands higher prices than that which is used under boilers in steel or affiliated plants. For example, the average unit prices for each of the groups classified in table 8 were the highest on record in 1947, but the composite or average unit value ($0.189 per M cubic feet) for all surplus gas was lower than the 1934 figure of $0.191 per M cubic feet. However, nearly 47 percent of the total quantity of surplus gas available in 1934 was distributed through city mains, whereas only 28 percent was so distributed in 1947 (table 8).

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TABLE 5. - Relationship of value of surplus gas sold or used by coke-plant operators to value of all coproducts sold

Year	Value of surplus gas sold or used	Value of all coproducts	Percent of total value from surplus gas
1919.....	$16,650,195	$63,727,790	26.1
1924.....	49,784,947	103,802,507	48.0
1929.....	84,304,270	163,675,571	51.5
1934.....	59,258,839	92,865,828	63.8
1939.....	71,876,455	124,814,434	57.6
1940.....	81,402,047	145,081,877	56.1
1941.....	85,040,609	158,809,184	53.5
1942.....	88,823,807	176,932,465	50.2
1943.....	88,620,185	181,929,705	48.7
1944.....	94,122,400	185,995,242	50.6
1945.....	87,745,022	172,138,205	51.0
1946.....	83,184,679	157,389,875	52.9
1947.....	112,008,007	222,093,651	50.4

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TABLE 6. - Coke-oven gas produced and methods of disposal

Year	Produced (MCF)	Used in heating ovens		Disposal of surplus coke-oven gas				
		Quantity (MCF)	Percent of total	Distributed through city mains (MCF)	Used (MCF)		Sold for industrial purposes (MCF)	Wasted (MCF)
					In steel or affiliated plants	Under boilers or other coke plant equipment		
1919.....	415,655,098	212,222,098	51.1	54,703,000	(1)	(1)	138,121,000	10,609,000
1924.....	541,101,050	229,298,247	42.4	65,676,867	187,171,883	29,794,046	18,561,057	10,598,950
1929.....	843,148,089	316,800,622	37.6	160,560,921	302,165,465	18,506,502	26,357,691	18,756,888
1934.....	493,581,751	175,868,523	35.6	144,308,149	119,716,459	29,324,006	16,222,743	8,141,871
1939.....	675,143,201	232,864,056	34.5	144,876,573	237,890,694	28,714,866	22,229,157	8,567,855
1940.....	833,761,720	297,566,103	35.7	151,688,271	305,890,735	36,498,403	29,563,146	12,555,062
1941.....	892,819,811	328,137,246	36.8	159,746,453	330,452,000	31,404,684	32,523,312	10,556,116
1942.....	944,879,637	344,412,807	36.5	169,530,544	335,290,705	49,414,260	31,219,576	15,011,745
1943.....	960,454,518	350,762,774	36.5	169,788,941	345,418,565	39,870,361	37,197,507	17,416,370
1944.....	1,008,799,926	373,024,121	37.0	170,313,905	384,933,114	30,111,380	35,803,212	14,614,194
1945.....	904,476,118	337,128,344	37.3	166,178,375	324,294,221	32,061,903	31,718,913	13,094,362
1946.....	783,637,016	293,685,525	37.5	157,234,511	265,545,711	29,473,813	28,235,551	9,461,905
1947.....	971,262,280	366,257,800	37.7	167,865,453	348,322,970	37,957,353	38,799,524	12,059,180

1/ Probably included with "Sold for industrial purposes."

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TABLE 7. - Disposal of coke-oven gas, percent

Year	Burned in coking process	Surplus sold or used otherwise	Wasted
1919.....	51.0	46.4	2.6
1924.....	42.4	55.6	2.0
1929.....	37.6	60.2	2.2
1934.....	35.6	62.8	1.6
1939.....	34.5	64.2	1.3
1940.....	35.7	62.8	1.5
1941.....	36.7	62.1	1.2
1942.....	36.4	62.0	1.6
1943.....	36.5	61.7	1.8
1944.....	37.0	61.6	1.4
1945.....	37.3	61.3	1.4
1946.....	37.5	61.3	1.2
1947.....	37.7	61.1	1.2

TABLE 8. - Distribution of surplus coke-oven gas

Year	Surplus gas (M cubic feet)	Disposal, percent			
		Distributed through city mains	In steel or affiliated plants	Under boilers or other coke plant equipment	Sold for industrial purposes
1919.....	192,824,094	28.4	(1)	(1)	71.6
1924.....	301,203,853	21.8	62.1	9.9	6.2
1929.....	507,590,579	31.6	59.5	3.7	5.2
1934.....	309,571,357	46.6	38.7	9.5	5.2
1939.....	433,711,290	33.4	54.9	6.6	5.1
1940.....	523,640,555	29.0	58.4	7.0	5.6
1941.....	554,126,449	28.8	59.6	5.7	5.9
1942.....	585,455,085	29.0	57.3	8.4	5.3
1943.....	592,275,374	28.7	58.3	6.7	6.3
1944.....	621,161,611	27.4	62.0	4.8	5.8
1945.....	554,253,412	30.0	58.5	5.8	5.7
1946.....	480,489,586	32.7	55.3	6.1	5.9
1947.....	592,945,300	28.4	58.7	6.4	6.5

1/ Included with "Sold for industrial purposes."

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TABLE 9. - Disposal of surplus coke-oven gas by merchant and furnace plants

Year	Under boilers (used by producer)					
	At merchant plants			At furnace plants		
	Quantity (MCF)	Value	Average	Quantity (MCF)	Value	Average
1919..	(1)	(1)	-	(1)	(1)	-
1924..	8,729,409	$377,206	$0.043	21,064,637	$1,351,807	$0.064
1929..	7,369,668	546,457	.074	11,136,834	735,870	.066
1934..	8,896,526	560,481	.063	20,427,480	2,313,092	.113
1939..	5,958,426	417,313	.070	22,756,440	1,549,829	.068
1940..	8,222,236	647,596	.079	28,276,167	2,000,732	.071
1941..	9,910,551	721,781	.073	21,494,133	1,643,878	.076
1942..	12,254,649	948,242	.077	27,521,412	2,379,821	.086
1943..	9,944,508	712,530	.072	18,684,340	1,605,306	.086
1944..	6,801,251	530,472	.078	23,310,129	2,115,379	.091
1945..	5,854,028	493,849	.084	26,207,875	2,604,501	.099
1946..	6,750,703	747,900	.111	22,723,110	2,559,301	.113
1947..	7,521,967	797,611	.106	30,435,386	3,679,689	.121
	In steel or affiliated plants (used by producer)					
1919..	(1)	(1)	-	(1)	(1)	-
1924..	-	-	-	187,171,883	$21,007,607	$0.112
1929..	969,959	$154,715	$0.160	301,195,506	31,746,789	.105
1934..	741,817	81,777	.110	118,974,642	10,920,087	.092
1939..	6,416,013	566,038	.088	231,474,681	23,735,022	.103
1940..	7,934,172	712,337	.090	297,956,563	30,459,338	.102
1941..	8,042,159	731,947	.091	322,409,841	33,716,933	.105
1942	11,748,935	956,815	.081	333,179,969	34,641,194	.104
1943..	13,767,606	1,105,330	.080	342,892,472	35,310,167	.103
1944..	13,112,419	1,264,546	.096	371,820,695	40,681,876	.109
1945..	10,700,637	1,035,529	.097	313,593,584	35,939,071	.115
1946..	6,609,132	842,374	.127	258,936,579	30,329,744	.117
1947..	6,735,333	925,872	.137	341,587,637	47,609,479	.139

1/ Included with "Sold for industrial purposes."

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TABLE 9. - Disposal of surplus coke-oven gas by merchant and furnace plants (Cont'd.)

Year	Distributed through city mains (sold)					
	From merchant plants			From furnace plants		
	Quantity (MCF)	Value	Average	Quantity (MCF)	Value	Average
1919..	2/46,487,450	$7,631,619	$0.164	2/8,215,637	$940,134	$0.114
1924..	47,224,266	20,077,733	.425	18,452,601	3,408,683	.185
1929..	115,934,449	38,344,102	.331	44,626,472	8,650,530	.194
1934..	116,679,201	36,772,872	.315	27,628,948	6,152,703	.223
1939..	107,542,354	34,835,122	.324	37,334,219	8,056,248	.216
1940..	110,869,308	35,306,372	.318	40,818,963	8,625,520	.211
1941..	113,804,836	34,611,865	.304	45,941,617	9,496,932	.207
1942..	120,185,225	35,854,767	.298	49,345,319	9,927,667	.201
1943..	117,690,158	34,444,537	.293	52,098,783	10,149,673	.195
1944..	116,613,951	34,707,240	.298	53,699,954	9,987,614	.186
1945..	113,585,983	33,866,855	.298	52,592,392	9,665,230	.184
1946..	107,982,090	35,555,286	.329	49,252,421	9,373,411	.190
1947..	113,512,038	42,273,402	.372	54,353,415	11,755,723	.216
	For industrial purposes (sold)					
1919..	8,564,274	$429,000	$0.050	129,556,733	$7,649,442	$0.059
1924..	6,074,684	2,280,881	.375	12,486,373	1,281,030	.103
1929..	12,907,233	2,405,809	.186	13,450,458	1,719,998	.128
1934..	9,000,216	1,325,989	.147	7,222,527	1,131,838	.157
1939..	14,569,173	1,898,750	.130	7,659,984	818,133	.107
1940..	17,392,923	2,386,297	.137	12,170,223	1,263,855	.104
1941..	19,299,386	2,816,749	.146	13,223,926	1,300,524	.098
1942..	19,133,279	2,904,180	.152	12,086,297	1,211,121	.100
1943..	19,940,427	3,199,759	.160	17,257,080	2,092,883	.121
1944..	21,218,839	3,099,694	.146	14,584,373	1,735,579	.119
1945..	17,340,080	2,304,854	.133	14,378,833	1,837,133	.128
1946..	15,012,978	2,003,891	.133	13,222,573	1,772,772	.134
1947..	20,708,177	2,853,119	.138	18,091,347	2,113,112	.117

2/ Includes figures classified as "For illuminating and household purposes" and "To public service corporations."

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COKE-OVEN TAR AND ITS DERIVATIVES

Crude coal tar. - High-temperature coke-oven tar is a black, rather thick, viscous liquid at ordinary temperature and is composed of a mixture of many different compounds. It is supposed that high-temperature coal tars contain over 200 definite chemical compounds, of which a far smaller number have been separated in pure condition and identified. In the early days of the oven-coke industry in the United States, most of the crude coal tar produced was used in its crude form by producers, mainly as fuel for open-hearth furnaces, with relatively small quantities used for boiler fuel and for other miscellaneous uses. Precise statistics on the disposal of coke-oven tar were not collected prior to 1929. The expansion in carbonizing capacity during and immediately after World War I greatly increased the production of tar, and several companies operated solely for the purpose of processing tar and marketing the products. In general, each of the processing companies operated distilling plants centrally located with respect to sources of tar supply. In the latter part of the 20's, some of the coke-plant operators began to partly refine or "top" their tar, and by 1929 over 43 million gallons were processed at coke plants. In this way the tar acids and other distillates were recovered and sold, and the resulting soft pitch was utilized as fuel. As the markets for tar products expanded, the quantities of tar refined by producers or sold for refining to other purchasers increased steadily, and the proportion of crude tar burned as fuel diminished. Thus, the percentage of crude tar burned as fuel declined from 51 percent of the production in 1929 to 21 percent in 1947. During this period, the proportion refined or "topped" by coke-oven operators increased from about 6 percent of the total output to 27 percent, whereas sales of coke-oven tar to independent tar refineries increased from 42 to 51 percent.

Coal-tar derivatives. - The principal commercial products obtained by coke-plant operators are tar acid oil and creosote oil. Roughly 60 percent of the crude tar processed remains as pitch. The disposal of large quantities of pitch has always been more or less a problem to the coke-plant operator and it is usually used as fuel. This accounts for the small quantities sold, as shown in table 12. Creosote oil, a tar distillate having a boiling range from 200° C. to 355° C. and used mainly for impregnating wood against decay, is the most important tar derivative produced at coke plants, accounting for about 55 percent of the revenue obtained from the sale of all tar derivatives. Although the quantity of creosote oil produced by coke-oven operators has increased sharply in the last decade, only about one-third of the total United States' production is recovered at coke ovens, as the bulk of the production comes from independent tar refineries. Beginning in 1941, the Bureau began the collection of statistics on tar acid oil, phenol, and cresols, but as there are fewer than three producers processing the tar distillate fractions for the recovery of phenol, cresols, and cresylic acid, figures are not publishable. Statistics on the output of tar acid oil, however, have been published since 1941 and are shown in table 12.

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TABLE 10. - Coke-oven tar produced, used by producers, and sold

Year	Produced		Used by producer					Sold			
			Burned		Refined			For refining		As fuel	
	Total (1,000 gal.)	Yield per ton of coal coked (gal.)	Quantity (1,000 gal.)	Percent of production	Quantity (1,000 gal.)	Percent of production	Otherwise1/ (1,000 gal.)	Quantity (1,000 gal.)	Percent of production	Quantity (1,000 gal.)	Percent of production
1919.....	288,902	8.06	-	-	-	-	-	2/217,707	75.4	-	-
1924.....	422,074	8.60	213,474	50.6	-	-	611	2/209,980	49.7	-	-
1929.....	680,864	8.87	298,050	43.8	43,019	6.3	1,146	285,069	41.9	48,489	7.1
1934.....	408,710	9.22	107,630	26.3	36,344	8.9	1,291	236,466	57.9	37,298	9.1
1939.....	554,406	9.06	90,021	16.2	111,783	20.2	877	278,392	50.0	66,143	11.9
1940.....	673,287	8.79	175,954	26.1	151,545	22.5	1,409	311,049	46.2	39,643	5.9
1941.....	704,149	8.52	139,316	19.8	184,197	26.2	1,401	377,791	53.7	14,749	2.1
1942.....	740,176	8.41	95,565	12.9	194,692	26.3	1,671	443,008	59.9	2,590	.3
1943.....	738,167	8.20	87,201	11.8	204,628	27.7	4,423	440,859	59.7	14,780	2.0
1944.....	767,807	8.13	157,598	20.5	200,570	26.1	5,166	391,338	51.0	15,851	2.1
1945.....	696,307	7.95	107,794	15.5	178,575	25.6	3,633	383,871	55.1	26,628	3.8
1946.....	596,869	7.82	65,753	11.0	155,061	26.0	2,781	367,037	61.5	10,962	1.8
1947.....	736,174	7.78	121,548	16.5	200,474	27.2	2,230	375,897	51.1	32,076	4.4

1/ For miscellaneous purposes such as tarring ingot moulds, making tar paint, etc.
2/ Total tar sold, purpose unspecified.

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TABLE 11. - Average yield of coke-oven tar per ton of coal carbonized, by States, gallons

State	1919	1924	1929	1934	1939	1940	1941	1942	1943	1944	1945	1946	1947
Alabama	7.51	8.22	9.10	9.54	8.64	8.58	8.49	8.47	8.36	8.31	8.26	7.97	7.83
California	-	-	-	-	-	-	-	-	10.92	10.71	10.48	10.13	10.15
Colorado	9.58	9.50	9.68	10.90	10.91	10.69	10.78	10.38	10.50	10.60	10.47	10.28	9.71
Illinois	5.78	7.95	7.57	8.88	8.33	7.90	7.43	7.43	7.63	6.95	6.84	6.71	6.56
Indiana	5.89	6.06	5.96	6.80	6.46	6.22	5.85	6.06	5.87	5.82	6.02	5.94	5.63
Maryland	6.30	6.84	7.44	7.61	8.29	7.69	7.86	7.81	7.67	7.56	7.08	7.38	7.00
Massachusetts	8.26	8.25	8.19	8.31	8.46	8.18	7.83	7.72	7.85	7.73	7.33	7.55	7.46
Michigan	7.17	7.56	8.19	8.55	8.89	8.44	8.12	7.95	7.64	7.36	7.31	7.20	6.94
Minnesota	7.41	8.40	7.96	8.12	8.66	8.69	7.89	6.66	6.61	6.56	7.00	6.34	5.96
New Jersey	10.31	8.41	8.13	7.89	8.09	8.19	8.23	8.14	7.97	7.63	6.81	7.42	7.64
New York	8.05	8.66	9.04	9.53	9.58	9.14	8.98	8.88	8.50	8.35	8.27	8.09	7.80
Ohio	8.70	9.02	8.77	9.09	8.55	8.16	7.85	7.72	7.25	7.44	7.06	6.90	6.88
Pennsylvania	9.57	9.91	10.68	10.69	10.57	10.22	10.03	9.82	9.62	9.59	9.23	9.10	9.20
Tennessee	7.95	8.86	6.85	5.69	7.25	7.37	6.90	7.18	6.95	6.81	7.44	7.55	7.65
Texas	-	-	-	-	-	-	-	-	-	8.33	8.35	-	6.52
Utah	-	10.38	11.40	10.04	11.50	11.66	11.24	11.14	10.62	10.39	11.85	11.36	11.54
Washington	6.72	8.24	8.30	6.80	-	-	-	-	10.33	-	-	-	-
West Virginia	9.14	11.28	10.10	11.53	11.07	11.11	11.05	10.50	10.34	10.28	10.27	10.50	10.55
Connecticut, Kentucky, Missouri, Rhode Island, and Wisconsin	7.41	8.25	7.49	7.81	8.09	8.17	8.17	7.98	7.89	7.72	7.28	7.21	7.31
	8.06	8.60	8.87	9.22	9.06	8.79	8.52	8.41	8.20	8.13	7.95	7.82	7.78
At merchant plants	7.68	7.18	8.27	8.75	8.79	8.72	8.62	8.59	8.40	8.19	7.81	7.72	7.77
At furnace plants	8.17	8.96	9.04	9.49	9.15	8.81	8.49	8.36	8.14	8.11	7.99	7.85	7.79

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TABLE 12. - Coke-oven tar refined by producers and creosote oil, tar acid oil, and pitch-of-tar recovered

Year	Tar refined, gallons[1]	Creosote oil		
		Produced, gallons	Sold	
			Gallons	Average value per gallon
1919.....	(2)	(2)	(2)	-
1924.....	(2)	(2)	(2)	-
1929.....	43,019,024	3/26,730,126	23,938,431	$0.096
1934.....	36,343,769	12,408,010	5,500,485	.083
1939.....	111,782,843	19,455,849	13,573,393	.108
1940.....	151,545,371	29,600,468	17,722,398	.110
1941.....	184,197,206	40,332,579	39,235,286	.117
1942.....	194,692,227	42,219,837	40,604,985	.119
1943.....	204,627,996	43,552,772	40,620,590	.128
1944.....	200,570,084	43,779,321	42,424,697	.120
1945.....	178,575,329	36,831,149	34,933,338	.124
1946.....	155,061,221	31,122,825	29,538,178	.127
1947.....	200,473,652	40,498,217	39,449,817	.160

Year	Tar acid oil			Pitch of tar		
	Produced, gallons	Sold		Produced, pounds	Sold	
		Gallons	Average value per gallon		Pounds	Average value per pound
1919....	(2)	(2)	-	(2)	(2)	-
1924....	(2)	(2)	-	(2)	(2)	-
1929....	(2)	(2)	-	176,314,934	11,197,224	$0.002
1934....	(2)	(2)	-	195,795,142	9,874,194	.003
1939....	(2)	(2)	-	430,828,382	4,218,231	.003
1940....	(2)	(2)	-	614,079,900	3,486,860	.003
1941....	11,675,741	11,794,218	$0.115	728,244,354	6,634,200	.004
1942....	17,921,998	11,340,244	.137	1,276,315,027	17,168,710	.007
1943....	15,165,320	15,160,304	.131	1,334,506,205	62,812,840	.007
1944....	13,432,236	13,405,255	.118	1,338,449,011	105,328,800	.005
1945....	13,800,408	13,657,097	.114	1,173,279,682	17,089,181	.005
1946....	12,953,198	13,270,360	.122	1,020,980,869	614,597	.005
1947....	13,201,290	12,927,441	.180	1,314,892,901	8,380,971	.011

1/ Includes tar topped.
2/ Data not collected.
3/ Includes an undetermined amount of road tar.

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TABLE 13. - Production of crude coal tar from all sources, gallons

Year	Coke-oven tar	Retort tar[1]	Medium- and low-temperature tar	Total	Percent from coke ovens
1919.....	288,901,739	53,146,421	(2)	342,048,160	84.5
1924.....	422,074,326	53,000,000	(2)	475,074,326	88.8
1929.....	680,864,366	56,000,000	(2)	736,864,366	92.4
1934.....	408,710,314	32,000,000	(2)	440,710,314	92.7
1939.....	554,406,216	20,000,000	(3)	574,406,216	96.5
1940.....	673,286,517	22,000,000	(3)	695,286,517	96.8
1941.....	704,149,468	22,000,000	(3)	726,149,468	97.0
1942.....	740,175,619	21,091,829	(3)	761,267,448	97.2
1943.....	738,166,968	19,848,868	(3)	758,015,836	97.4
1944.....	767,807,171	19,719,133	3,893,646	791,419,950	97.0
1945.....	696,307,311	19,836,840	3,200,332	719,344,483	96.8
1946.....	596,868,745	17,464,392	1,931,688	616,264,825	96.9
1947.....	736,174,480	14,996,074	2,168,077	753,338,631	97.7

1/ 1919 and 1929, Bureau of the Census; 1924 and 1934-41, estimated by authors; 1942-47, Bureau of Mines.
2/ Not available.
3/ Included with coke-oven tar.

CRUDE LIGHT OIL AND ITS DERIVATIVES

Crude light oil is a term used in the coke industry to designate a mixture of products derived from the coking process, the boiling points of which do not exceed 200° C. It consists principally of benzol, toluol, and their homologs. The general method of recovering crude light oil in the United States is by scrubbing the coke-oven gas (freed from tar and ammonia) with a petroleum oil generally called "straw oil" or benzol wash oil. Between 90 and 95 percent of the "total light oil" produced in coal carbonization is recovered by scrubbing the gas, less than 5 percent is found in the tar, and the balance passes out with the scrubbed gas. The yield of crude light oil per ton of coal carbonized increased notably between 1919 and 1939 but since that year has declined steadily.

Since World War I, when the recovery of light-oil products became an important part of the coke industry, there has been considerable variation in the demands for the various kinds of products into which crude light oil can be refined. Table 18 shows the trend in the relative yields of the light oil products. The need for explosives in World War I stimulated the demand for toluol and benzol, and as coke ovens were the only source of these important chemicals at that time, the output from ovens increased greatly. After the war, the demand for toluol for the manufacture of explosives diminished, but the demand for benzol for blending with gasoline for use in internal-combustion engines increased because of its high "anti-knock" properties, and the greatest proportion of the crude light oil was refined into the "motor benzol" grade. This practice was employed until the beginning of World War II, when the requirements for pure benzol and pure toluol (essential raw materials in the manufacture of explosives,

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synthetic rubber, aviation gasoline, plastics, and other war materials) soared to unprecedented levels, thereby curtailing the production of motor benzol. In World War II, coke ovens were not the principal source of toluol, as technological developments in the refining of petroleum enabled this country to obtain most of its toluol from petroleum; coke ovens supplied only about one-fourth of the total requirements. After the second world war, the production of toluol dropper sharply to prewar levels, whereas the production of aniline, phenol, styrene, and cyclic intermediates generally continued at the wartime pace, and production of industrial benzol, the essential raw material, continued at an extremely high rate. Table 3 shows the trend in the prices received for the light-oil products since 1919.

Naphthalene is currently recovered at coke plants from the refining of crude light oil and of tar and from the final coolers. However, as more than 50 percent of the naphthalene recovered by coke-plant operators is obtained from light oil, statistics on this chemical are shown with the light oil derivatives. The amount of crude naphthalene produced at coke plants depends in large measure upon the price that this and related products command. As a source of revenue to the coke-oven operator, naphthalene is of small consequence, but as a raw material for the manufacture of alkyd resins, dyestuffs, and organic chemicals, it occupies an important place. Table 19 shows the production and sales of this commodity and indicates the receipts per ton of coke produced.

TABLE 14. - Coke-oven crude light oil produced, refined, and derived products obtained, gallons

Year	Produced	Yield per ton of coal coked	Refined on premises	Derived products obtained
1919.....	93,604,122	2.72	(1)	92,046,906
1924.....	128,956,955	2.89	125,580,743	100,928,015
1929.....	200,594,027	2.93	194,882,679	163,018,085
1934.....	115,694,748	2.90	108,219,464	94,570,139
1939.....	170,963,199	2.99	163,947,167	139,805,191
1940.....	215,213,667	2.93	207,272,848	177,794,631
1941.....	231,358,897	2.90	225,294,298	194,713,669
1942.....	246,024,882	2.88	241,854,110	206,155,160
1943.....	250,511,095	2.83	245,893,002	208,932,084
1944.....	267,861,984	2.87	259,544,535	222,436,683
1945.....	245,687,253	2.84	234,802,231	202,669,566
1946.....	206,914,333	2.77	198,593,963	171,607,226
1947.....	254,978,463	2.75	241,379,524	208,404,180

1/ Not available.

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TABLE 15. - Average yield of crude light oil per ton of coal carbonized, by States, gallons

State	1919	1924	1929	1934	1939	1940	1941	1942	1943	1944	1945	1946	1947
Alabama	2.17	2.70	2.92	2.94	3.00	2.88	2.92	2.88	2.74	2.85	2.82	2.77	2.76
California	-	-	-	-	-	-	-	-	2.52	3.87	3.36	3.53	3.72
Colorado	2.73	3.32	3.28	3.36	3.38	3.29	3.17	3.00	3.10	3.56	3.28	3.12	3.07
Illinois	2.11	2.67	2.56	2.48	2.55	2.43	2.39	2.45	2.56	2.68	2.65	2.64	2.64
Indiana	2.45	2.44	2.70	2.89	2.59	2.63	2.46	2.44	2.19	2.42	2.53	2.25	2.31
Maryland	1.77	1.94	2.52	3.49	3.31	3.43	3.44	3.59	3.62	4.04	3.97	3.87	4.09
Michigan	2.32	2.10	2.53	2.55	2.95	2.83	2.84	2.94	2.94	2.85	2.83	2.74	2.67
New York	2.65	2.98	2.74	2.29	2.55	2.69	2.62	2.75	2.73	2.50	2.60	2.56	2.17
Ohio	3.44	3.27	3.10	3.02	2.92	3.02	2.97	2.91	2.77	2.86	2.78	2.75	2.72
Pennsylvania	2.73	3.13	3.19	3.40	3.44	3.14	3.19	3.16	3.10	3.09	3.02	3.02	3.11
Tennessee	2.53	2.90	2.42	2.50	2.44	2.41	2.34	2.10	2.40	2.65	2.55	2.46	2.40
Texas	-	-	-	-	-	-	-	-	-	2.06	2.47	-	2.51
Utah	-	3.46	4.08	3.60	4.14	4.16	4.17	4.17	4.07	3.18	4.32	4.28	3.88
West Virginia	3.21	3.67	3.15	3.11	3.46	3.48	3.42	3.21	3.66	3.65	3.47	3.48	3.28
Connecticut, Kentucky, Massachusetts, Minnesota, Missouri, New Jersey, and Wisconsin.	2.56	2.43	2.19	2.53	2.45	2.52	2.48	2.34	2.47	2.42	2.20	2.14	1.79
	2.72	2.89	2.93	2.90	2.99	2.93	2.90	2.88	2.83	2.87	2.84	2.77	2.75
At merchant plants	2.44	2.19	2.46	2.36	2.48	2.43	2.53	2.61	2.53	2.50	2.35	2.21	2.15
At furnace plants	2.79	3.00	3.02	3.14	3.12	3.05	2.99	2.96	2.91	2.96	2.97	2.93	2.90

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TABLE 16. - Light-oil derivatives produced at oven-coke plants, gallons

Year	Benzol		Toluol crude and refined	Xylol crude and refined	Solvent naphtha	Other light-oil derivatives
	Motor	All other grades				
1919.....	44,544,311	17,006,532	1,160,136	(1)	3,920,489	575,885
1924.....	73,768,811	18,135,025	3,185,431	(1)	4,474,220	1,364,528
1929.....	105,923,762	24,944,531	18,343,295	(2)	7,131,111	6,675,386
1934.....	50,046,610	21,690,879	13,281,794	2,736,295	3,048,744	3,765,817
1939.....	79,607,150	25,305,714	19,767,200	4,089,090	4,788,836	6,247,201
1940.....	101,140,079	31,880,556	26,406,407	5,645,993	5,220,979	7,500,617
1941.....	106,372,015	37,883,480	29,337,178	7,619,200	5,283,034	8,218,762
1942.....	64,797,595	85,256,998	32,314,560	9,332,273	5,215,617	9,238,117
1943.....	21,267,932	132,439,174	32,272,593	8,763,927	5,232,848	8,955,610
1944.....	18,556,555	146,909,883	33,528,232	8,668,740	5,564,012	9,209,261
1945.....	28,788,072	126,670,542	27,069,321	7,504,115	4,802,748	7,834,768
1946.....	27,398,866	109,728,963	16,519,763	5,986,250	4,401,158	7,572,226
1947.....	15,802,689	145,057,916	26,396,449	7,130,332	5,647,563	8,369,231

1/ Data not collected. 2/ Included with solvent naphtha.

TABLE 17. - Benzol and toluol produced at oven-coke plants, by grades, gallons

Year	Benzol				Toluol		
	Motor	Nitration or 1° C.	Pure commercial or 2° C.	All other	Nitration or 1° C.	Pure commercial or 2° C.	All other
1941.....	106,372,000	15,414,500	18,286,400	4,182,600	14,689,800	13,268,500	1,378,900
1942.....	64,797,600	25,624,400	53,617,900	6,014,700	25,160,200	5,044,800	2,109,600
1943.....	21,267,900	35,047,800	93,246,600	4,144,800	27,152,300	2,394,700	2,725,600
1944.....	18,556,600	41,285,800	102,436,500	3,187,600	29,771,100	2,149,600	1,607,500
1945.....	28,788,100	39,166,500	86,237,300	1,266,700	23,355,400	2,219,700	1,494,200
1946.....	27,398,900	35,739,300	71,681,700	2,308,000	12,518,000	2,796,400	1,205,400
1947.....	15,802,700	42,475,300	100,111,800	2,470,800	20,514,100	4,989,500	892,800

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TABLE 18. - Trend in yields of products obtained from refining crude light oil at oven-coke plants, percent

Year	Benzol		Toluol	Xylol	Solvent naphtha	Other light oil products
	Motor	All other grades	crude and refined	crude and refined		
1919.....	(1)	(1)	(1)	(1)	(1)	(1)
1924.....	61.8	11.4	2.5	(1)	3.6	1.1
1929.....	54.4	12.8	9.4	(2)	3.7	3.4
1934.....	46.2	20.0	12.3	2.5	2.8	3.5
1939.....	48.6	15.4	12.1	2.5	2.9	3.8
1940.....	48.8	15.4	12.7	2.7	2.5	3.6
1941.....	47.2	16.8	13.0	3.4	2.3	3.6
1942.....	26.8	35.3	13.4	3.9	2.2	3.8
1943.....	8.6	53.9	13.1	3.6	2.1	3.6
1944.....	7.1	56.6	12.9	3.3	2.1	3.5
1945.....	12.3	53.9	11.5	3.2	2.0	3.3
1946.....	13.8	55.3	8.3	3.0	2.2	3.8
1947.....	6.5	60.1	10.9	3.0	2.3	3.5

1/ Not available. 2/ Included with solvent naphtha.

TABLE 19. - Production and sales of naphthalene by coke-plant operators

Year	Production, pounds	Sales		Average receipts per pound	Receipts per ton of coke
		Quantity, pounds	Value		
1919.....	6,343,269	6,702,040	$191,364	$0.029	$0.008
1924.....	8,391,968	8,219,073	128,208	.016	.004
1929.....	19,761,382	19,659,367	320,272	.016	.006
1934.....	10,743,471	10,500,285	131,299	.013	.004
1939.....	48,460,171	46,551,432	727,947	.016	.017
1940.....	72,426,443	72,522,476	1,248,051	.017	.023
1941.....	84,046,676	83,879,396	1,522,518	.018	.026
1942.....	95,612,788	95,039,639	1,941,626	.020	.031
1943.....	98,096,899	98,031,058	2,088,829	.021	.033
1944.....	103,041,023	103,839,789	2,094,596	.020	.031
1945.....	87,677,299	86,936,517	1,806,967	.021	.029
1946.....	71,605,138	71,769,750	1,602,739	.022	.030
1947.....	98,378,875	98,364,997	3,021,152	.031	.045

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COKE-OVEN AMMONIA

In coal carbonization, ammonia is recovered either as its water solution (ammonia liquor) or as a crystallized ammonium sulfate. Usually, about 85 percent of the total ammonia recovered in the coking process is converted to ammonium sulfate and is sold as a fertilizer material. Production of coke-oven ammonia increased rapidly in the early 20's, rising from 93,307 short tons in 1919 to 214,054 tons in 1929. The depression that followed the stock-market crash in the fall of 1929 stopped new oven construction, and operation of ovens in existence was drastically curtailed. As a consequence, coke-oven ammonia production dropped sharply in the following 10-year period. The gathering war clouds in 1939 made it necessary not only to step up coking operations but also to increase the coal-carbonization capacity in order to meet the demand for coke and related products for military purposes. Output of coke-oven ammonia increased rapidly in the ensuing years, reaching a peak of 236,226 tons in 1944. Although production declined somewhat from this figure after the end of World War II, the shortages of nitrogenous fertilizers throughout the world placed requirements at extremely high levels, and output in 1947 was the highest on record in a peacetime year. In view of the rising demand for fertilizer materials, it is likely that output of coke-oven ammonia in 1948 and for several years to come will exceed the all-time peak of 1944.

Before and during World War I, coke ovens were the principal source of chemical nitrogen in the United States (table 23). This permitted coke-plant operators to obtain high prices for the liquor and sulfate sold, and in 1913 ammonia gave the operators the greatest income of the coal chemicals; in World War I, the demand for explosives gave the value of light oil and its derivatives temporary leadership over ammonia, which, however, was regained by the latter in 1918 and continued until 1921, when the value of gas forged ahead of the other coal chemicals, and ammonia began to decline, a trend that continued until the end of World War II. This decline may be attributed largely to the great development in the fixation of atmospheric nitrogen by Haber in Germany in 1913, which was introduced in the United States in the middle 20's and now accounts for more than 80 percent of the total output.

The remarkable growth of the synthetic-nitrogen industry in the United States has had a profound effect upon the price of ammonium sulfate. Up to 1920, the price of nitrogen in ammonium sulfate and other nitrogen products followed the price set for the nitrogen in sodium nitrate largely imported from Chile. The influence of the synthetic products on the price of nitrogenous fertilizers is shown in table 24 by comparison of the wholesale prices of a number of these products since 1919. A unit of nitrogen, 20 pounds, is taken as the basis for comparison.

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TABLE 20. - Coke-oven ammonia produced at merchant and furnace plants, net tons

Year	Merchant			Furnace			Total NH_3 equivalent	Total nitrogen content
	Sulfate	Liquor	NH_3 equivalent	Sulfate	Liquor	NH_3 equivalent		
1919..	22,978	15,977	21,722	249,174	9,291	71,585	93,307	76,792
1924..	44,948	15,998	27,235	401,615	8,517	108,921	136,156	112,056
1929..	110,639	21,484	49,144	633,518	6,530	164,910	214,054	176,166
1934..	97,442	17,439	41,800	295,280	4,358	78,178	119,978	98,742
1939..	101,800	16,131	41,581	478,475	8,001	127,620	169,201	139,252
1940..	108,382	18,790	45,886	609,849	9,679	162,141	208,027	171,206
1941..	111,512	20,569	48,447	633,686	10,820	169,242	217,689	179,158
1942..	116,237	23,009	52,068	650,567	10,919	173,380	225,448	185,544
1943..	111,787	20,313	48,260	649,483	13,793	176,164	224,424	184,701
1944..	109,503	18,989	46,365	708,741	12,676	189,861	236,226	194,414
1945..	105,799	17,338	43,788	658,494	10,269	174,893	218,681	179,974
1946..	98,854	16,381	41,095	544,898	8,611	144,836	185,931	153,021
1947..	105,674	17,074	43,493	703,766	8,644	184,586	228,079	187,709

TABLE 21. - Yield of ammonium sulfate or equivalent, as reported by coke-plant operators

	1921	1929	1939	1947
Total recovered.....millions of pounds	657	1,712	1,354	1,825
Yield of sulfate per ton of coal carbonized:				
Minimum average reported.....pounds	3.6	9.8	9.8	4.0
Maximum average reported..... do.	30.3	31.4	30.0	27.8
At average plant[1]..... do.	21.9	23.0	21.9	19.5
Average for all coal carbonized[2]..... do.	22.8	22.3	22.3	19.7
Number of plants recovering ammonia.....	67	87	80	82
Number of plants recovering -				
Less than 10 pounds per ton of coal.....	2	1	1	3
10 - 14.9 pounds.....	2	1	4	7
15 - 19.9 pounds.....	14	8	16	29
20 - 21.9 pounds.....	11	21	11	24
22 - 23.9 pounds.....	13	24	25	11
24 - 25.9 pounds.....	15	19	14	3
26 - 27.9 pounds.....	3	9	8	5
28 - 29.9 pounds.....	6	3	1	-
30 pounds or more.....	1	1	-	-

1/ Sum of averages for all plants divided by number of plants.
2/ Total yield in sulfate equivalent divided by number of tons of coal carbonized.

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TABLE 22. - Average yield of ammonium sulfate or equivalent per ton of coal carbonized, by States, pounds

State	1919	1924	1929	1934	1939	1940	1941	1942	1943	1944	1945	1946	1947
Alabama	20.07	22.68	25.15	26.20	24.58	24.01	24.68	24.03	23.78	23.56	23.22	22.70	22.44
California	-	-	-	-	-	-	-	-	21.30	27.43	27.41	26.21	27.79
Colorado	21.73	20.99	21.56	23.93	23.61	23.46	22.71	23.18	22.36	22.85	22.29	21.42	20.75
Illinois	18.44	21.55	21.85	23.13	21.14	20.72	19.40	19.10	19.61	18.77	17.88	19.34	18.90
Indiana	17.41	16.23	17.34	18.10	18.39	17.98	16.46	17.10	16.47	17.18	17.74	17.30	16.37
Maryland	18.42	19.81	20.44	20.95	22.21	19.98	18.44	17.36	19.19	20.42	21.39	19.98	20.34
Massachusetts	19.50	19.20	20.44	22.25	22.95	23.04	20.62	18.49	17.18	17.50	17.16	17.36	16.76
Michigan	19.79	24.14	22.02	22.00	21.03	20.89	22.02	21.23	20.99	20.36	20.91	21.03	20.20
Minnesota	18.56	20.85	22.42	-	22.35	22.56	20.61	17.80	17.72	17.55	17.31	16.73	15.02
New Jersey	27.17	22.83	22.45	19.88	20.98	20.19	20.86	20.39	19.52	18.09	17.27	18.11	18.23
New York	17.30	21.48	22.82	21.97	22.35	21.79	21.17	20.53	20.03	19.15	18.96	19.29	18.04
Ohio	23.33	23.78	23.18	21.45	22.27	21.88	20.89	20.42	19.16	19.31	19.03	18.47	18.15
Pennsylvania	21.44	23.44	22.96	23.50	23.65	23.48	22.96	22.43	21.75	21.65	21.55	20.76	21.29
Tennessee	21.55	26.69	20.08	24.65	26.05	24.39	20.87	19.44	20.68	22.69	22.84	21.85	22.52
Texas	-	-	-	-	-	-	-	-	-	23.36	26.54	-	21.78
Utah	-	25.39	28.80	23.93	26.57	27.67	27.61	27.32	26.50	24.89	25.71	25.09	26.21
Washington	32.32	32.97	31.44	-	-	-	-	-	-	-	-	-	-
West Virginia	22.76	24.84	23.75	23.62	24.61	24.38	25.20	22.54	23.69	23.52	23.32	21.72	22.58
Connecticut, Kentucky, Missouri, Rhode Island, and Wisconsin	20.65	23.38	22.18	21.64	20.83	21.54	21.95	21.04	20.92	19.83	19.73	19.35	19.27
	20.82	22.20	22.31	22.29	22.33	22.00	21.34	20.85	20.32	20.29	20.22	19.79	19.66
At merchant plants	20.69	21.88	22.93	21.76	22.29	22.22	21.96	21.33	20.76	20.31	19.75	19.73	19.32
At furnace plants	20.86	22.28	22.13	22.58	22.34	21.94	21.17	20.71	20.20	20.28	20.34	19.80	19.74

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TABLE 23. - Production of chemical nitrogen from all sources, net tons

Year	Coke ovens	All other sources[1]	Total	Percent of total from coke ovens
1919.....	76,792	6,208	83,000	92.5
1924.....	112,056	17,586	129,642	86.4
1929.....	176,166	142,713	318,879	55.2
1934.....	98,742	157,959	256,701	38.5
1939.....	139,252	284,583	423,835	32.9
1940.....	171,206	329,980	501,186	34.2
1941.....	179,158	414,620	593,778	30.2
1942.....	185,544	582,901	768,445	24.1
1943.....	184,701	876,535	1,061,236	17.4
1944.....	194,414	1,017,993	1,212,407	16.0
1945.....	179,974	881,692	1,061,666	17.0
1946.....	153,021	704,152	857,173	17.9
1947.....	187,709	1,181,366	1,369,075	13.7

1/ Does not include organic nitrogen from animal and vegetable sources.

TABLE 24. - Prices of selected nitrogen materials[1]

Year	Sodium nitrate	Ammonium sulfate	Anhydrous ammonia	Calcium cyanamide	Urea[2]
1919.....	2/$4.50	3/$3.88	(4)	(4)	(4)
1924.....	2.99	2.44	(4)	5/$2.20	(4)
1929.....	2.57	2.04	$1.46	1.90	$2.20
1934.....	1.52	1.20	1.09	1.20	2.21
1939.....	1.69	1.35	1.09	1.16	2.06
1940.....	1.69	1.36	1.09	1.33	1.96
1941.....	1.69	1.41	1.09	1.48	1.80
1942.....	1.69	1.41	1.09	1.74	1.80
1943.....	1.75	1.42	1.09	1.74	1.62
1944.....	1.75	1.42	1.09	1.74	1.62
1945.....	1.75	1.42	.82	1.74	1.62
1946.....	1.97	1.44	.82	1.80	1.48
1947.....	2.50	1.60	.74	2.20	1.54

1/ U. S. Department of Agriculture.
2/ Oil, Paint, and Drug Reporter.
3/ Steel f.o.b. producers' works.
4/ Not readily available.
5/ 1925.

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TABLE 25. - Production, sales, and value of ammonium sulfate at oven-coke plants, by regions, net tons

	1919	1924	1929	1934	1939
New England:					
Production	4,658	5,517	18,252	21,888	,
Sales	4,342	5,885	16,867	20,592	21,298
Value of sales	$382,838	$344,901	$666,394	$435,559	$479,497
Average	$88.17	$58.61	$39.51	$21.15	$22.51
Middle Atlantic:					
Production	103,818	182,049	337,079	186,183	279,438
Sales	107,277	188,647	325,827	190,095	281,938
Value of sales	$7,927,654	$8,811,181	$11,406,923	$3,627,466	$6,440,113
Average	$73.90	$46.71	$35.01	$19.08	$22.84
Ohio:					
Production	76,743	84,991	120,409	47,809	76,954
Sales	76,510	86,106	116,216	41,886	74,786
Value of sales	$5,916,387	$4,257,287	$4,030,285	$789,284	$1,692,664
Average	$77.33	$49.44	$34.68	$18.84	$22.63
Illinois-Indiana:					
Production	42,704	61,605	115,464	52,875	81,614
Sales	47,248	69,621	110,896	53,092	78,442
Value of sales	$3,673,122	$3,183,496	$3,945,140	$981,698	$1,688,410
Average	$77.74	$45.73	$35.58	$18.49	$21.52
Lake Dock:					
Production	7,619	14,942	31,650	17,753	22,173
Sales	6,568	13,377	28,099	18,528	23,329
Value of sales	$566,150	$697,343	$1,340,745	$377,884	$466,562
Average	$86.20	$52.13	$47.72	$20.40	$20.00
Southeastern:					
Production	30,146	87,126	105,233	60,798	87,879
Sales	30,337	91,771	103,201	59,383	87,027
Value of sales	$2,348,218	$4,687,404	$3,934,217	$1,206,533	$2,126,549
Average	$77.40	$51.08	$38.12	$20.32	$24.44
Western:					
Production	6,464	10,334	16,070	5,416	11,422
Sales	6,464	10,258	15,627	4,982	10,131
Value of sales	$547,095	$540,636	$537,775	$82,736	$259,847
Average	$84.64	$52.70	$34.41	$16.61	$25.65
Total:					
Production	272,152	446,564	744,157	392,722	580,274
Sales	278,746	465,665	716,733	388,558	576,951
Value of sales	$21,361,464	$22,522,248	$25,861,479	$7,501,160	$13,153,642
Average	$76.63	$48.37	$36.08	$19.31	$22.80

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TABLE 25. - Production, sales, and value of ammonium sulfate at oven-coke plants, by regions, net tons (Cont'd.)

	1940	1941	1942	1943	1944
New England:					
Production.....	22,497	21,337	20,247	19,295	18,944
Sales.....	21,930	21,860	20,198	19,603	17,816
Value of sales..	$519,086	$633,115	$577,473	$557,764	$507,071
Average.....	$23.67	$28.96	$28.59	$28.45	$28.46
Middle Atlantic:					
Production.....	347,501	356,220	362,351	358,746	369,200
Sales.....	352,949	358,752	345,817	367,456	341,123
Value of sales..	$8,738,036	$9,483,424	$9,042,041	$9,673,971	$8,581,162
Average.....	$24.76	$26.43	$26.15	$26.33	$25.16
Ohio:					
Production.....	101,174	113,586	111,791	108,801	111,326
Sales.....	103,590	116,616	110,760	109,552	111,603
Value of sales..	$2,506,057	$2,929,372	$2,740,824	$2,730,709	$2,705,217
Average.....	$24.19	$25.12	$24.75	$24.93	$24.24
Illinois-Indiana:					
Production.....	106,305	112,021	116,918	120,525	135,791
Sales.....	104,787	114,888	121,822	120,442	127,209
Value of sales..	$2,405,382	$2,777,100	$3,017,522	$2,999,223	$3,129,957
Average.....	$22.95	$24.17	$24.77	$24.90	$24.60
Lake Dock:					
Production.....	26,603	26,383	27,810	25,755	25,408
Sales.....	24,733	26,936	28,979	26,344	24,987
Value of sales..	$554,999	$649,330	$684,097	$653,011	$607,836
Average.....	$22.44	$24.11	$23.61	$24.79	$24.33
Southeastern:					
Production.....	99,074	99,310	110,319	104,958	118,021
Sales.....	103,253	99,857	107,907	106,808	115,069
Value of sales..	$2,752,766	$2,734,857	$2,893,510	$2,815,598	$3,051,128
Average.....	$26.66	$27.39	$26.81	$26.36	$26.52
Western:					
Production.....	15,077	16,341	17,368	23,190	39,554
Sales.....	15,262	17,660	16,431	24,610	39,155
Value of sales..	$399,842	$501,448	$504,738	$781,390	$1,246,112
Average.....	$26.20	$28.39	$30.72	$31.75	$31.83
Total:					
Production.....	718,231	745,198	766,804	761,270	818,244
Sales.....	726,504	756,569	751,914	774,815	776,962
Value of sales..	$19,876,168	$17,708,646	$19,460,205	$20,211,666	$19,828,483
Average.....	$24.61	$26.05	$25.88	$26.09	$25.52

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TABLE 25. - Production, sales, and value of ammonium sulfate at oven-coke plants, by regions, net tons (Cont'd.)

	1945	1946	1947
New England:			
Production	19,856	18,184	20,117
Sales	20,554	18,351	20,098
Value of sales	$578,596	$531,459	$662,911
Average	$28.15	$28.96	$32.98
Middle Atlantic:			
Production	340,464	284,672	358,820
Sales	372,783	282,951	360,126
Value of sales	$9,423,454	$7,771,871	$11,801,632
Average	$25.28	$27.47	$32.77
Ohio:			
Production	100,029	86,501	102,202
Sales	98,443	88,009	101,877
Value of sales	$2,408,450	$2,397,920	$3,258,170
Average	$24.47	$27.25	$31.98
Illinois-Indiana:			
Production	129,379	110,122	133,816
Sales	133,035	111,038	134,062
Value of sales	$3,298,657	$2,999,650	$4,175,547
Average	$24.80	$27.01	$31.15
Lake Dock:			
Production	25,132	23,052	23,135
Sales	24,757	22,104	24,703
Value of sales	$625,513	$836,887	$1,027,216
Average	$25.27	$37.86	$41.58
Southeastern:			
Production	113,404	96,668	125,756
Sales	115,001	96,570	124,576
Value of sales	$3,048,508	$2,740,981	$4,182,518
Average	$26.51	$28.38	$33.57
Western:			
Production	36,029	24,553	45,594
Sales	36,489	23,213	46,807
Value of sales	$1,150,900	$745,995	$1,616,827
Average	$31.54	$32.14	$34.54
Total:			
Production	764,293	643,752	809,440
Sales	801,062	642,236	812,249
Value of sales	$20,534,078	$18,024,763	$26,724,821
Average	$25.63	$28.07	$32.90

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TABLE 26. - Production, sales, and value of ammonia liquor (NH_3 content) at oven-coke plants, by regions, net tons

	1919	1924	1929	1934	1939
New England:					
Production.....	435	568	119	157	1,161
Sales.....	419	572	119	122	1,163
Value of sales..	$69,851	$85,823	$10,492	$6,169	$43,056
Average.....	$166.71	$150.04	$88.17	$50.57	$37.02
Middle Atlantic:					
Production.....	4,441	3,525	3,907	5,274	4,704
Sales.....	4,418	3,630	3,926	5,219	4,685
Value of sales..	$811,509	$708,038	$410,818	$323,838	$335,971
Average.....	$183.68	$195.05	$104.64	$62.05	$71.71
Ohio:					
Production.....	3,522	3,792	5,590	4,408	4,784
Sales.....	3,572	3,992	5,535	4,281	4,772
Value of sales..	$730,250	$715,606	$544,028	$260,339	$323,083
Average.....	$204.44	$179.26	$98.29	$60.81	$67.70
Illinois-Indiana:					
Production.....	6,790	6,497	7,454	3,060	3,398
Sales.....	6,949	7,019	7,336	2,770	3,342
Value of sales..	$1,511,383	$1,288,151	$729,426	$165,345	$218,858
Average.....	$217.50	$183.52	$99.43	$59.69	$65.49
Lake Dock:					
Production.....	5,886	7,566	7,516	7,354	7,084
Sales.....	6,325	6,049	7,390	7,106	7,097
Value of sales..	$1,493,589	$1,309,332	$765,578	$397,081	$361,435
Average.....	$236.14	$216.45	$103.60	$55.88	$50.93
Southeastern:					
Production.....	4,016	2,274	3,169	1,544	3,001
Sales.....	3,961	2,279	3,169	1,369	2,958
Value of sales..	$1,050,046	$507,024	$355,173	$77,577	$198,476
Average.....	$265.10	$222.48	$112.08	$56.67	$67.10
Western:					
Production.....	178	293	259	-	-
Sales.....	179	292	260	-	-
Value of sales..	$26,322	$42,454	$5,287	-	-
Average.....	$147.05	$145.39	$20.33	-	-
Total:					
Production.....	25,268	24,515	28,014	21,797	24,132
Sales.....	25,823	23,833	27,735	20,867	24,017
Value of sales..	$5,692,950	$4,656,428	$2,820,802	$1,230,349	$1,480,879
Average.....	$220.46	$195.38	$101.71	$58.96	$61.66

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TABLE 26. - Production, sales, and value of ammonia liquor (NH_3 content) at oven-coke plants, by regions, net tons (Cont'd.)

	1940	1941	1942	1943	1944
New England:					
Production.....	1,375	1,144	1,116	1,040	1,136
Sales.....	1,385	1,144	1,109	1,047	1,133
Value of sales..	$54,111	$57,069	$60,452	$54,770	$61,941
Average.....	$39.07	$49.89	$54.51	$52.31	$54.67
Middle Atlantic:					
Production.....	5,364	4,531	4,723	4,816	4,478
Sales.....	5,394	4,540	4.674	4,638	4,307
Value of sales..	$391,187	$338,001	$364,706	$357,034	$278,845
Average.....	$72.52	$74.45	$78.03	$76.98	$64.74
Ohio:					
Production.....	4,930	5,438	7,106	6,974	6,896
Sales.....	4,975	4,886	6,416	6,279	6,399
Value of sales..	$353,676	$346,819	$496,502	$478,681	$424,410
Average.....	$71.09	$70.98	$77.38	$76.24	$66.32
Illinois-Indiana:					
Production.....	4,545	5,636	5,383	5,916	5,678
Sales.....	4,377	5,820	5,410	5,830	5,688
Value of sales..	$305,141	$409,403	$389,876	$410,282	$342,828
Average.....	$69.71	$70.34	$72.07	$70.37	$60.27
Lake Dock:					
Production.....	7,812	9,040	9,574	9.225	8,939
Sales.....	7,594	8,217	8,279	8,329	7,931
Value of sales..	$379,873	$434,910	$462,012	$631,659	$500,934
Average.....	$50.02	$52.93	$55.81	$75.84	$63.16
Southeastern:					
Production.....	4,443	5,600	6,025	6,135	4,538
Sales.....	4,400	5,564	6,050	6,204	4,546
Value of sales..	$314,121	$414,771	$464,819	$475,024	$305,827
Average.....	$71.39	$74.55	$76.83	$76.57	$67.27
Western:					
Production.....	-	-	-	-	-
Sales.....	-	-	-	-	-
Value of sales..	-	-	-	-	-
Average.....	-	-	-	-	-
Total:					
Production.....	28,469	31,389	33,927	34,106	31,665
Sales.....	28,125	30,171	31,938	32,327	30,004
Value of sales..	$1,798,109	$2,000,973	$2,238,367	$2,407,450	$1,914,785
Average.....	$63.93	$66.32	$70.08	$74.47	$63.82

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TABLE 26. - Production, sales, and value of ammonia liquor (NH_3 content) at oven-coke plants, by regions, net tons (Cont'd.)

	1945	1946	1947
New England:			
Production	567	474	453
Sales	575	477	453
Value of sales	$22,639	$18,157	$20,978
Average	$39.37	$38.06	$46.31
Middle Atlantic:			
Production	4,240	3,903	3,817
Sales	4,133	3,761	3,703
Value of sales	$254,696	$234,945	$234,733
Average	$61.62	$62.47	$63.39
Ohio:			
Production	6,387	5,900	6,682
Sales	5,674	5,279	5,944
Value of sales	$350,912	$329,420	$378,743
Average	$61.85	$62.40	$63.72
Illinois-Indiana:			
Production	3,748	3,066	3,144
Sales	3,801	3,134	2,914
Value of sales	$210,952	$162,878	$170,106
Average	$55.50	$51.97	$58.38
Lake Dock:			
Production	8,531	7,811	8,430
Sales	7,489	6,963	7,391
Value of sales	$454,105	$420,924	$462,936
Average	$60.64	$60.45	$62.64
Southeastern:			
Production	4,134	3,837	3,192
Sales	4,048	3,907	3,214
Value of sales	$262,797	$250,972	$203,804
Average	$64.92	$64.24	$63.41
Western:			
Production	-	-	-
Sales	-	-	-
Value of sales	-	-	-
Average	-	-	-
Total:			
Production	27,607	24,991	25,718
Sales	25,720	23,521	23,619
Value of sales	$1,556,101	$1,417,296	$1,471,300
Average	$60.50	$60.26	$62.29

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